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## Patterns in Authoring of Adaptive Educational Hypermedia: A Taxonomy of Learning Styles

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### ABSTRACT

This paper describes the use of adaptation patterns in the task of formulating standards for adaptive educational hypermedia (AEH) systems that is currently under investigation by the EU ADAPT project. Within this project, design dimensions for high granularity patterns have been established. In this paper we focus on detailing lower granularity adaptive patterns based upon learning styles. Several patterns from existing AEH system case studies are identified and classified according to an extended learning style "onion" model. This model forms the basis of a learning style taxonomy, introduced here, whose components determine adaptation patterns for AEH. These patterns are of importance both for authoring, as well as for interfacing between adaptive hypermedia systems. From an authoring point of view, these patterns may be used to establish a fine-grain approach to instructional strategies that can be implemented in AEH systems, as a response to a particular learning style. The implementation of this *adaptation pattern* taxonomy is discussed, both generally and in detail.

### Keywords:

Adaptive education hypermedia, Learning styles, Taxonomy, Adaptation design patterns, ADAPT.

### Introduction

Since the web has become an important platform for the delivery of educational experiences, many attempts have been made to utilise techniques of Adaptive Hypertext (AH) to personalise the learning process (Brusilovsky, 2001). The goal of the various Adaptive Educational Hypermedia (AEH) systems that have been developed in recent years has been to avoid the "one size fits all" mentality that is all too common in the design of web-based learning systems. The fundamental problem is that learners inevitably have diverse backgrounds, abilities and motivation – and hence highly individual learning requirements. This is well known to educationalists (Barbe & Milone, 1981; Corno & Snow 1986; Felder, 1993), but seemingly not always appreciated by the designers of technology-based learning. Most early attempts at AEH were based around simple knowledge-based user models. While this is a perfectly valid approach, it is also very limited because it only addresses one aspect of user diversity – that of prior experience and ability. It does not address the far more fundamental psychological issue, that there are very substantial differences between individuals in the cognitive mechanisms by which we all learn (Coffield *et al*, 2004).

The ultimate objective of AEH is to create the 'perfect' online lesson for every learner – utilising a common set of learning resources. The 'rules' that are used to describe the creation of such a system are not yet standardised, and the criteria that need to be used for pedagogically effective rule-sets are, as yet, poorly understood. Many experimental AEH systems have been created - each to their own unique specifications. As yet, however, no combined effort has been made to extract the common design paradigms from these systems. Learning styles are one such possible common design paradigms for AEH systems. Learning style models have been researched and used by educationalists for many years, and some of them have been implemented in Intelligent Tutoring Systems (ITS). Recently a small subset has been implemented in AEH systems. For example: WHURLE (Brown & Brailsford, 2004; Moore *et al*, 2001), CS383 (Carver *et al*, 1999) and ILASH (Bajraktarevic *et al*, 2003) all implement different aspects of the Felder-Soloman ILS (Index of Learning Styles) (Felder & Soloman, 2004). Others such as INSPIRE (Grigoriadou *et al*, 2001) uses Kolb's theory of experiential learning (Kolb, 1984); or the Dunn and Dunn model (Dunn & Dunn, 1978) as used in iWeaver (Wolf, 2002).

The fact that learning styles can now be implemented in AEH systems, even to this limited degree, is promising, and ensures that these systems can be used in future with greater effectiveness. However, although we salute these initial attempts, most of them make the same mistake as early adaptive hypermedia research: the ‘intelligence’ of the system (i.e., the specification of the dynamics and behaviour) is hidden within the system and is system-dependent. As learning style specification is more complex than the knowledge-based strategies implemented in early AEH systems, this method of implementation will result in even less reusability. This is one reason why it is of vital importance to extract patterns for AEH, at different granularity levels, starting from the ADAPT dimensions, to learning styles, all the way to the fine-grained implementation steps that are required in the instructional strategy corresponding to a particular learning style.

Another strong case for the necessity of pattern extraction is made by the authoring process itself. In previous research (Cristea & De Bra, 2002; Cristea & De Mooij, 2003b) we have already identified the need for patterns in order to ease the author’s burden. Indeed, an adaptive educational hypermedia author has not only to create linear courseware (the same as their non-adaptive e-learning counterpart) but also create all the different alternatives of this courseware. Speaking in terms of dynamic, personalized course behaviour, the author has to specify the different strategies that go with each particular learning style that may occur within the target learner group. It is quite obvious that potential authors consider this an insurmountable task and stick with linear courseware, ignoring the benefits that personalization can bring to the learning experience of their students. In order to help such authors, a multitude of templates for instructional strategies based in our case on learning styles, has to be available and ready to use. Moreover, these strategies have to be kept as independent as possible from the domain, so they can be reused in different contexts and for different learning materials.

In the following section this paper briefly describes the design dimensions extracted within the EU project ADAPT (2004). These dimensions define the whole space for adaptation pattern definition. Next, we introduce a new learning style taxonomy organized towards the categorization of specific learning-style induced adaptation patterns that are implemented or can be implemented in adaptive educational hypermedia. Then, an implementation of these patterns is presented. Finally, in the last two sections we discuss our proposal and our findings and draw some conclusions.

## **Adaptation patterns and ADAPT**

ADAPT is an European Community funded project (ADAPT, 2004) that aims to rectify the situation described in the introduction, by investigating current adaptive practices in various AEH environments (mature or still under development) and identifying the design patterns within them. A design pattern is defined in (Alexander et al, 1977) as a recurrent problem and its (heuristic) solution (i.e. most solutions will be heuristic, although it is not inconceivable that some non-heuristic solutions may be found).

The ADAPT project has identified high level design dimensions for AEH systems (Garzotto & Cristea, 2004), loosely based on LAOS, a framework for Adaptive Hypermedia Authoring (Cristea & de Mooij, 2003a), which are:

- context of use (CU),
- content domain (DM),
- instructional strategy (IS),
- instructional view (IV),
- learner model (LM),
- adaptation model (AM) and
- detection mechanism (DE).

These dimensions form the axes on which both an AEH problem and its solution can be represented. This means that any subset of instances from the design dimensions can actually formulate the problem, and subsets of instantiations of the rest of the variables, the solution. This set of [problem, solution] is the basis of a pattern, as initially defined by Alexander et al (1977). Other possible elements of a pattern are: name, context, forces, related patterns, and known uses. These elements actually add more information to each particular pattern, but also increase the dimensions of the result.

Figure 1 shows the transformation of the initial design dimensions into a specific pattern, by selecting one dimension as the problem dimension and all the remaining dimensions becoming the solution (the pentagon surface in the figure). The surface delimited by the corners of the pentagon shows the actual instance of the solution, given the instance problem. Please note that there is no restriction that the problem or solution should

have the dimension of a point (they could be an interval as well). In other words, multiple solutions are possible for a problem, and therefore, the pentagon's dimensions can vary. The problem in this case was depicted as the vertical axis, to clearly separate it from the rest. Please also note that the formulation of the problem can determine this division between the axes (some of them participating in the problem formulation, and the others participating in the solution to that given problem).

As a concrete example of such an instance, if the recurrent problem is described as designing an AEH for beginner users (IS: beginner), a possible solution can be an instantiation of the other dimensions as:

CU: academia, K12 or others (similar treatment is performed for any CU)

DM: Introduction, Informal Definition, Summary

IV: tour

LM: knowledge (overlay model)

AM: uses rules such as: if current concept in tour read, then display (link to) next concept

DE: knowledge of user about concept is increased when concept is accessed

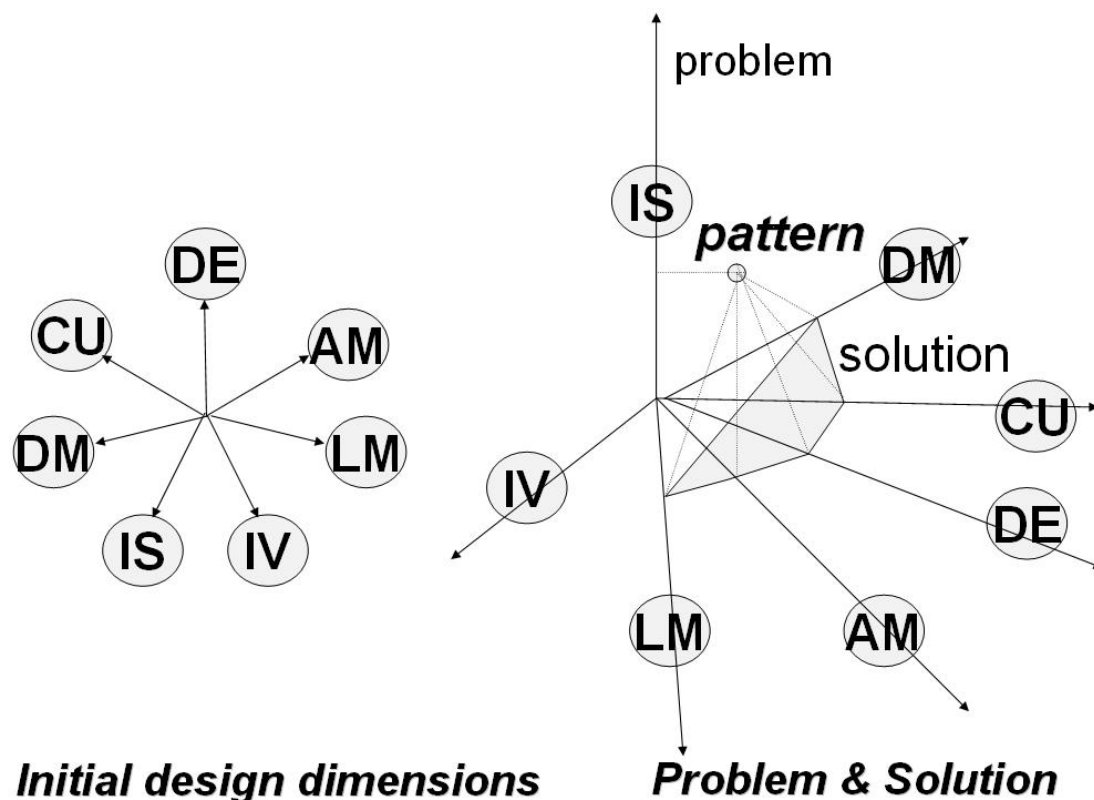


Figure 1. ADAPT design dimensions as problem versus solution

This is only one possible solution to the problem posed above, forming one possible pattern. Please note that some elements of the solution may induce clustering. For instance, it may be possible to conceive that beginners in academia are treated differently to beginners in K12, etc. In reality, the discovery of appropriate design patterns is a non-trivial task. The design dimensions described above represent the start of what must be an ongoing process. Using this framework it is possible to develop a taxonomy of patterns and their associated sub-patterns. Although a complete pattern taxonomy remains a long way off, it is currently quite possible to derive a taxonomy for specific components of the model. In this paper we describe one such taxonomy for learning styles (which are a subsection of the 'Learner Model' (LM) in adaptive systems).

The primary purpose of the proposals contained in this paper is to provoke thought and initiate more discussion within the wider community on this very important issue.

Recently, the ADAPT project has initiated a series of workshops on this topic. For instance, the paper of Garzotto *et al.* (2003) from the first of these workshops attempts to "identify examples of 'good matches'

between learning styles and application design solutions”, “to be used as design guidelines both for educational hypermedia and for adaptive or adaptable educational hypermedia”. In their approach, “the problem component of a design pattern is described by an instructional goal (e.g., a learning preference that the designer, or the application, needs to address); the solution component describes the desired design properties that the application should have, concerning its types of content, its organization structures, and interaction or navigation capabilities”. Their design dimensions are: Concepts and Content, Interaction, Navigation, Activity, Layout. These dimensions are inherited from previous studies on static hypermedia design, upon which learning styles have been overlaid. The problem is that adaptivity, and the adaptive component (such as our adaptation model) are not yet clearly defined, although parts may be identified within the Interaction, Navigation and Activity dimensions. What they correctly identify is the interaction of these dimensions. However, by deciding that their problem can only be an instructional goal, the authors limit the usability of their model.

Avgeriou *et al.* (2003) are tackling the issue of design patterns in adaptive web-based educational systems. Their paper mainly details user model patterns, as they correctly identify them as the basis of adaptivity in personalized hypermedia. However they base their overall pattern system directly on the AHAM reference model for adaptive hypermedia (Wu, 2002). This means, therefore, that they miss elements of the detection mechanism, which are not explicit in the AHAM model. More importantly, they miss a clear, semantically relevant definition of the adaptation model of the adaptive hypermedia system. As in AHAM there is no distinction between instructional strategy, instructional view and adaptation model, all of them overlapping in the teaching model. The user (or learner) model patterns that they are identifying are however useful and of fine granularity. Their user model doesn’t cater for learning styles as such, but has a dimension ‘stereotype’, which could also be interpreted as learning style dimension.

## Learning Style Taxonomy

### Categorising Learning Style Models

There are many different learning style models. A recent report suggested there may be as many as 71 currently in use (Coffield *et al.*, 2004) although many of them suffer from low internal reliability and a lack of empirical evidence. Of these models, many derive from a common ancestry and measure similar dimensions, e.g. Pask’s holist-serialist style (Pask, 1972) and Felder-Soloman’s global-sequential style (Felder & Soloman, 2004). In addition to this vast collection of learning style theories, there is also a wealth of confusing terminology and assessment tools. It is little wonder then, that many researchers are overwhelmed by the choice of which instruments may be better than others, or which theories may be trusted more than others, or simply which learning styles “work” in any given context. For example, the terms ‘learning style’, ‘cognitive style’ and ‘information processing style’ are all terms that have been used interchangeably by various researchers, in a rather inconsistent and confusing manner. The term ‘learning style’ has been used in this paper as an overarching term that is meant to include any psychological or educational model used in researching cognitive processes applied in a learning situation..

There has been much research into the efficacy of learning styles as a tool to enhance learning; a comprehensive review of this research, along with strengths and weaknesses of several approaches, can be found in Coffield *et al.* (2004). Each approach has its merits, and documented in Coffield’s report are various case studies showing where these can be most effective. The learning style models used by current AEH systems exploit some of these more popular models. It seems as if there is no optimum learning style as such: each has its own advantages and disadvantages, and thus its own unique consequences depending on the environment in which it is used. The important issue is that AEH systems are starting to take note of crucial pedagogical issues in order to enhance the learning experience. Moreover, they are paving at the same time the way for larger scale experiments of validation or invalidation of learning instruments based on learning styles.

Many researchers have attempted to construct overviews of learning styles, such as Rayner and Riding (1997), de Bello (1990), Swanson (1995), Cassidy (2003) and Coffield *et al.* (2004). These are extremely comprehensive works, and are recommended for further reading.

Curry’s onion model is a good basis for demonstrating the different ways in which learning styles can be categorised (Curry, 1983; Curry, 1987), by assigning them to a particular layer in a radial system, with a structure analogous to that of an onion. These layers correspond extremely well to the different types of learning style models and because of this, it has been chosen as an aid to representing our model visually. Moreover,

rather than building a model from scratch, we preferred to search the literature for the model which is closest to our representation and suitable for adaptive hypermedia systems.

Figure 2 displays our extended Curry's onion model. The only extension is the prior knowledge layer, which will be explained later. The innermost layer, cognitive processing style, seeks to measure an individual's personality, specifically related to how they prefer to acquire and integrate information. Moving outwards, the next layer measures information processing style and examines a learner's intellectual approach to assimilation of new information. The layer beyond that examines social interaction, and how students prefer to interact with each other. The outermost layer, of instructional preference, tends to relate to external factors such as physiological and environmental stimuli associated with learning activities. The layers refer to different aspects of learning style, and those most influenced by external factors (and most observable) are on the outermost layers. The innermost layers are considered to be more stable psychological constructs and less susceptible to change; however these are much less easily measured.

These dimensions of the Learning Style within the User Model, are to be refined further. In comparison with the learning style dimensions proposed in Garzotto et al (2003), we opt for an arguably more expressive, semantically relevant dimension definition. For instance, their input definition can map over information processing style, instructional preference and social interaction, without specifically being attributable to any one of them.

### Learning Style Models Within AEH Systems

Several learning style models have been implemented in adaptive educational hypermedia systems; Table 1 below matches up the some of the systems and the approaches upon which they base their learning preferences.

Of the learning style models mentioned in the table, it can be seen that these utilise instructional preferences (Dunn and Dunn), information processing (Kolb; some of the Felder-Soloman aspects) and cognitive personality dimensions (Witkins', plus other Felder-Soloman aspects) of Curry's onion framework. Social interaction models of learning style have not been incorporated into any existing AEH systems though this is hardly surprising. Whilst these important models are studied in computer supported collaborative learning (CSCL) and computer supported collaborative work (CSCW), they are as currently a complex issue for AEH.

Another construct associated with learning style is a *student's prior knowledge*; this is seen in many AH systems such as AHA! (De Bra *et al*, 2003) and WHURLE (Zakaria & Brailsford, 2002). This construct should be taken into consideration when creating a taxonomy, and thus could be added as an extra layer to Curry's model since there is currently no layer that could accurately represent this type of learning style.

Table 1. Overview of learning style models in extant AEH systems

AEH system:	Learning style model:
AES-CS (Triantafillou, 2002)	Witkin's field dependence/independence (Witkin & Goodenough, 1981)
iWeaver (Wolf, 2002)	Dunn and Dunn's learning style model (Dunn & Dunn, 1978)
INSPIRE (Grigoriadou <i>et al</i> , 2001) MOT (2004) (Stash <i>et al</i> , 2004)	Kolb's theory of experiential learning (Kolb, 1984)
AHA! (De Bra <i>et al</i> , 2003; Stash <i>et al</i> , 2004)	Honey and Mumford's Learning Styles Questionnaire (Honey and Mumford, 1992)
CS383 (Carver <i>et al</i> , 1999)	Felder-Soloman Inventory of Learning Styles (Felder & Soloman, 2004)
ILASH (Bajraktarevic, 2003)	
TANGOW - extended version (Paredes & Rodriguez, 2003)	
WHURLE (Brown & Brailsford, 2004)	

Höök & Svensson (1999) and Abou-Jaoude & Frasson (1999) suggest semantic layers of user modelling, that include the dimensions already mentioned, together with aspects such as motivation and believability. The latter are related to emotions, cognition and personality and seem to integrate well with the innermost layer of the onion model (cognitive personality style).

## Taxonomies

### Coarse-grain taxonomy

From examining how learning styles may be categorised, and seeing how these are actually implemented in AEH systems, it is possible to create a broad classification of learning style models for use within the ‘Learner Model’ dimension of the ADAPT project (ADAPT, 2004). What we propose is an extended version of Curry’s onion model, that integrates prior knowledge as an additional layer, as shown by the diagram below.

The layers shown in Figure 2 are modified from the original version of Curry’s onion model and use the same concepts to map each level (right hand side). AEH systems currently using learning style models are categorised into appropriate layers (on the right-hand side).

It is also worth noting that instructional preference could include for example, hardware platforms, as well as general environmental or physiological stimuli. In this manner, learners may express a preference for ambient or mobile learning, possibly delivered by PDA or mobile phone.

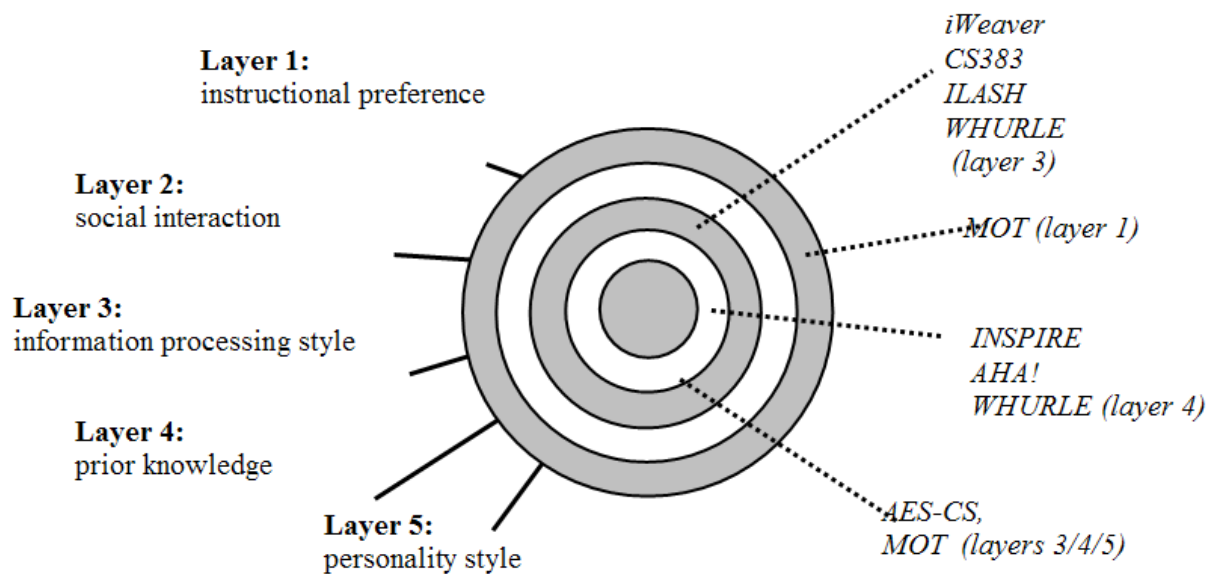


Figure 2. Extended Curry’s onion model of learning style theories (Curry, 1983; Curry, 1987)

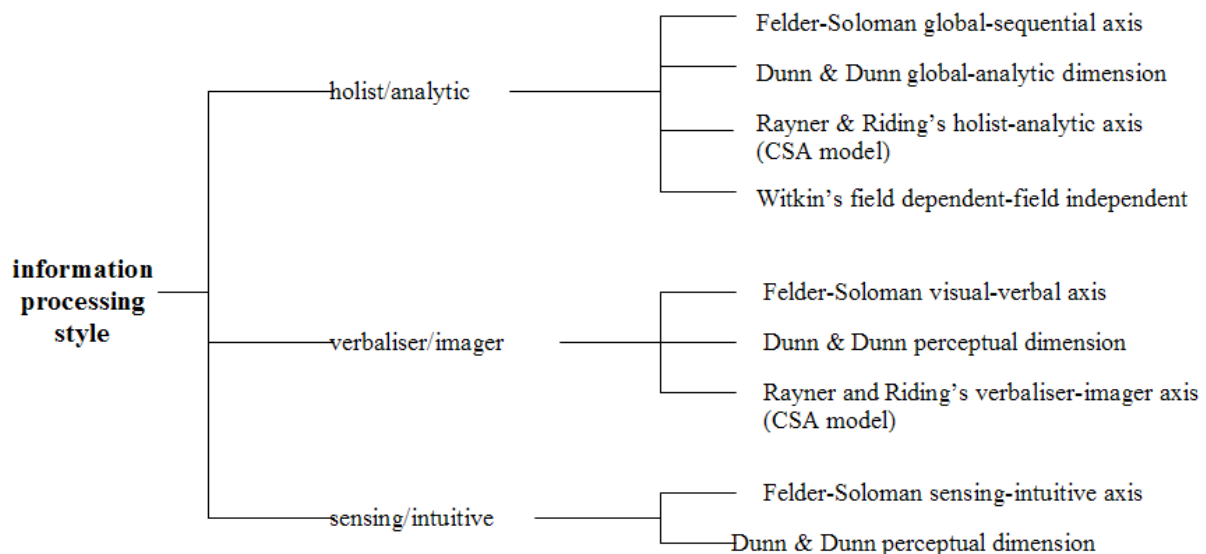


Figure 3. Fine granularity of the information processing layer

### *Fine-grain taxonomy*

There are several specific learning style theories currently in use within AEH systems, taken from defined categories of ‘learning styles’. Since most of the AEH systems shown in Figure 2 are contained within the ‘information processing’ layer, it seems prudent to explore this in more detail. Figure 3 depicts a fine-grain taxonomy of this particular classification of learning style theory.

Information processing can be sub-divided into three sections: holist/analytic; verbaliser/imager and sensing/intuitive. These in turn relate to specific dimensions of learning styles, exemplified by design problems and their related solutions, together forming fine-grain patterns.

### *Integrating patterns with taxonomy*

Each of the leaves defining a specific learning style in Figure 3 represents a problem typical for educational environments, and therefore, a problem that AEHs should be able to tackle. By providing each leaf with a specific solution, we can populate the ends of the tree with patterns corresponding to the fine-grain classification within the current taxonomy.

To illustrate this, we look at the information processing style corresponding to the holistic/analytic learner in Figure 3, defined as a preference for field dependency (as opposed to field independence). The pattern emerging from this problem description is listed in Table 2.

The table shows instantiated the ADAPT dimensions for AEH systems. The vertical axis on the right hand side of Figure 1 is again the *instructional strategy (IS)*, which is instantiated here with a strategy for field dependence.

Table 2 shows that the *context of use (CU)* of the field dependent instructional strategy covers academia, K12 education, vocational training, handicapped learners, etc. It also shows that the *content domain (DM)* for field dependence can use resource types such as fact, phenomenon, etc. Field dependent learners are known to need overviews of the learning material. Therefore, the *instructional view (IV)* should provide them with a map of where there are and how they are progressing, e.g., as is typically done in AEH, a hierarchical ordering of the domain concepts.

*Table 2.* An AEH pattern describing the preference for field dependency and its possible solutions using the ADAPT design dimensions

<b>Problem:</b>	
IS:	field dependent
<b>Solution:</b>	
CU:	academia, K12, vocational training, handicapped learners, others
DM:	Fact, Phenomenon, Principle, Example, Formal Definition, Informal Definition, Procedure (“how to do”), Process, Hands on, Theory, Demonstration, Quotation, Simulation, Introduction, Pattern, Summary, LOM
IV:	hierarchical order of domain model concepts (levels)
LM:	knowledge (overlay model)
AM:	uses rules such as: if current level has been accessed, display (links to) the other level
DE:	knowledge of user about concept is increased when concept is accessed

For the *adaptation model (AM)*, a breadth-first approach to the presentation of the material is preferred in the literature (Stach & De Bra, 2003). Therefore, the learner should only be able to access the next level of a greater depth, after the current level has been understood.

Finally, the *detection mechanism (DM)* for field dependent learners is knowledge-based, as in most AEH.

The core problem presented in this paper, that of how a taxonomy of learning styles can help with the classifying of adaptation patterns, is in this way addressed. In our model, patterns are gradually refined, starting from high level patterns, such as at the level of the ADAPT dimensions, and then moving on to lower level patterns, such as the Learning Style Taxonomy within the User model dimension of the initial pattern system. Following that,



we have finer granularity dimensions, such as the ones represented in Figure 3, for the Learning Style dimension of the Information Processing style.

Therefore, a [problem, solution] pair can be written, for example in Table 2, with much finer granularity and precision. The points and intervals on the ADAPT dimensions in Figure 1 are detailed this way.

However, refining from high level patterns such as the ADAPT dimensions to individual learning styles doesn't have to be the end of the process. The instructional strategies that correspond to learning styles can be further broken down into a specific adaptation language, which caters for AEH purposes, representing yet another gradation of detail. This will be described further in the following sections.

## Implementing the Taxonomy

The ADAPT project not only aims to suggest adaptive pattern taxonomies, such as the ones presented in the previous sections, but also to create an environment in which these patterns can be readily implemented and tested.

In order to show in practice how the taxonomy affects the authoring interface of an extant system, we are using the AEH authoring environment MOT (ADAPT, 2004; Cristea & de Mooij, 2003b).

In order to verify that using an authoring environment respecting the taxonomy of learning styles and the ADAPT dimensions is general enough to be detached from the actual delivery process, two different AEH delivery systems, WHURLE (Moore *et al*, 2003) and AHA! (De Bra *et al*, 2003) are used.

Finally, we show how the learning style taxonomy can be refined, based on the adaptation model, LAG (Cristea & Calvi, 2003).

### Authoring conform to Patterns in MOT

My Online Teacher (MOT, 2004; Cristea & de Mooij, 2003b) is an AEH system developed using the LAOS generic framework for Authoring of Adaptive Hypermedia (Cristea, 2003; Cristea & de Mooij 2003a). For the purposes of this paper we will concentrate solely on its main capability: authoring. MOT is a generic authoring system that allows for rapid and flexible authoring of:

- *Domain Maps* (represented as a conceptual model); corresponds to the ADAPT dimension *content domain (DM)*;
- *Lessons*; (representing a filtered, goal-oriented version of one or more domain maps) ; corresponds to the ADAPT dimension *instructional strategy (IS)* as well as *context of use (CU)*;;
- *User Maps* (built according to an overlay model of the domain and lessons, expressing, .e.g., the knowledge of a learner for a given concept in a concept map; as well as containing loose user attributes, such as background knowledge; this functionality is still under construction); corresponds to the ADAPT dimension *learner model (LM)*;
- *Presentation Maps* (containing the machine related presentation issues, such as the display colour or format; this functionality is under construction); corresponds to the ADAPT dimension *instructional view (IV)*; and
- *Adaptive Strategies* (using the LAG model by Cristea & Calvi (2003), further detailed in the following sections), corresponds to the ADAPT dimension *adaptation model (AM)*.

It is this last, unique, capability that makes it of such value for our purposes. Using this model it is possible create adaptive rules based, among other things, around various Learning Style models.

The only ADAPT dimension presently unavailable in MOT is the *detection mechanism (DE)*. This dimension influences more the delivery system than the authoring system. For example from the point of view of authoring, 'access' is just another variable.

MOT is a flexible and self-contained AEH system, but (as with most AEH systems) on its own it can only author materials that are destined to be delivered within its own environment. Recent research (Stewart *et al*, 2004; Stash *et al*, 2004) has initiated the move away from this one to one authoring paradigm (i.e. authoring is dedicated to a single system), towards a one to many one (i.e. where one system is used for authoring, but the delivery can be in a number of systems). One of the major aims of this research is to enable inter-operability of

data between diverse AEH systems. As a first step towards these ends, interfacing software has been developed to allow MOT to be used as the authoring platform for materials that may subsequently be delivered in either AHA! (De Bra *et al*, 2003) or WHURLE (Moore *et al*, 2003).

MOT is a highly flexible system that may be used to author both content and adaptation rules (using MOT-adapt, an implementation of the LAG model). For example, the MOT to WHURLE conversion of pedagogic adaptation rules is controlled by the authors' description of the content in a lesson (Stewart *et al*, 2004), allowing for different pedagogic models to be created in MOT and used in WHURLE. The authors have created lessons adapting to either the learners background knowledge or their position within a simplified visual/verbal Felder-Soloman ILS continuum. Due to lack of space, the conversion and its results will not be further detailed here.

The separation of content authoring (in MOT) and adaptation rule authoring (in MOT-adapt) creates an even more flexible and powerful authoring system with inter-operability and re-use of different layers of the LAOS model between entirely distinct AEH environments.

### The LAG model

The LAG model (Cristea & Calvi, 2003) is a theoretical model that is the basis of the adaptation model in MOT. It consists of three authoring levels for AEH:

- the *direct adaptation techniques* (such as simple IF-THEN rules, also called 'adaptation assembly language' in (Cristea & Calvi, 2003));
- the *adaptation language* (a wrapper over the direct adaptation techniques, grouping these into language constructs which are considered meaningful for adaptive education delivery; e.g., a 'generalize' rule for traversing the domain concept tree from child to father concepts; this can be useful when the information in the child concept is too specific, and a more general overview is necessary);
- the *adaptation strategies* (actually, *adaptation procedures* for smaller size pieces of code that can become new adaptation language constructs, extending the adaptation language, and adaptation strategies corresponding to specific instructional strategies).

Further details about the LAG model, and the adaptation language are beyond the scope of this paper, but are discussed in Cristea & Calvi (2003).

This model is useful in the current context because of the last layer, that of adaptation strategies. Such a strategy can be designed to express a specific instructional strategy, which in turn responds to the needs of a specific learning style. Therefore, the LAG model represents, from the point of view of pattern extraction, the breaking down of the Learning Style dimension into the corresponding Instructional Strategy, and further on, into adaptation language constructs and finally adaptation techniques. In this way, a learning style can be characterized in terms of the adaptation language constructs (or adaptation procedures) that have to appear in the strategy that corresponds to it.

### Authoring Adaptive Patterns in MOT

Figure 4 illustrates this with the implementation of the adaptive features of the pattern (the adaptation model), in the form of an adaptation strategy in MOT. Keeping with the example in section '*Integrating patterns with taxonomy*', it shows the description of a strategy for field dependent learners, edited in MOT-adapt.

Figure 5 shows the same strategy implemented. This is a simple implementation, using the LAG adaptation language (MOT-adapt). The hierarchical structure of the domain concepts in MOT (which is not detailed here, but can be found in Cristea & de Mooij, 2003b) is used to give the learner with field dependent preferences a depth-first view on the learning material.

Both strategy description and implementation can be done by the same author, or by different ones. Reuse at the level of the adaptive strategy can happen when another author reads only the description of the strategy and decides to use it as is.

**You chose to**

☒ Create a new strategy

Name your new strategy:

Enter a description for the new strategy:

FD(): strategy for users who see the global picture and ignore the details (until later), requiring external defined goals and reinforcements. they need navigation and orientation support.  
 A simple way of implementation is breadth-first approach.

OK

Figure 4. Description of Field Dependent adaptation strategy

The snapshot in Figure 5 lets the learner start at *depth=1*, which is the starting depth for this user map (UM), then loops as long as there are still concepts by calling another procedure not detailed here, *readleveldepth*, which displays to the reader only the material at a given depth in the MOT concept hierarchy. When the level is read, the depth is increased by one, and the whole process repeated.

```

[add statement]
* UM.Concept.depth = 1
[add statement]
while * UM.Concept.finish == false do
( [add statement]
  readleveldepth
  [add statement]
  * UM.Concept.depth += 1
  [add statement]
)
[label]
[add statement]

```

Figure 5. Implementation of Field Dependent adaptation strategy

Therefore, the actual LAG adaptation language constructs used for the definition of this strategy are: *action*, *while* and the new procedure *readleveldepth*. These represent adaptation patterns, as they can be reused in a different contexts. For the refinement of the solution specification, this means that the pattern formed by the [problem, solution] pair in Table 2, will be extended as shown in Table 3.

The solution presented in Table 3 is not stating that for field dependent learners only academia can be used as content domain. Rather, this restriction is inherited from MOT, which is a system currently aimed at students. This represents both a refinement and a clustering of the solution, just as mentioned in section ‘Adaptation patterns and ADAPT’. This extra restriction allows for instance the adaptation model to be restricted to *action*, *while* and *readleveldepth* rules. It is a constrained solution, which therefore enforces an explicit set of implementation elements. However, this solution keeps enough generality to serve as a reusable pattern,

applicable to another similar context. Other examples of patterns at the level of MOT adaptation strategies catering to different learning styles can be found in Stash *et al.* (2004).

*Table 3.* A refined AEH pattern describing the preference for field dependency and its possible solutions using the ADAPT design dimensions and the LAG adaptation language.

<b>Problem:</b>	
IS:	field dependent
<b>Solution:</b>	
CU:	academia
DM:	Fact, Phenomenon, Principle, Example, Formal Definition, Informal Definition, Theory, Quotation, Introduction, Pattern, Summary,
IV:	hierarchical order of domain model concepts (levels)
LM:	knowledge (overlay model)
AM:	Uses <i>action</i> , <i>while</i> and <i>readleveldepth</i> uses rules such as: if current level has been accessed, display (links to) the other level
DE:	access of concepts (influences knowledge of user)

## Discussion

The ADAPT project has already formalized the high-level design dimensions and corresponding patterns for AEH systems. This paper advances the search for adaptive patterns one step further by proposing a fine scale taxonomy for one aspect of these high level patterns, namely that of learning styles.

We also introduce a mechanism for the implementation and testing of the models within the taxonomy – the LAG model implemented in MOT. This of course is only the first stage in the implementation of learning style models with an AEH. MOT is only one AEH authoring system amongst many. To be truly valuable to the AEH community, the authoring of adaptive strategies in MOT should be AEH system independent. That is: an author writes a strategy once and can subsequently use it in multiple AEH systems. Work is currently ongoing in this area, with the individual content blocks, the overlying lesson structure, and adaptive strategies of MOT being transformed – so that they will function with any of the AEH systems that are part of the ADAPT project. Ultimately the aim is to produce an API that will allow system developers to write their own interface with the MOT authoring environment.

Towards this end, we look at different common design paradigms. A taxonomy of the extant Learning Style models would be an important research tool for pattern detection. It would aid in the creation of AEH user models and would address such questions as what user parameters need to be recorded; how these parameters would affect adaptation and how adaptation could occur (either at content or link level, or both)? It would also provide a good introduction for researchers new to the field; not only would the models themselves be explained, but also information relating to empirical evidence and internal validity (i.e. the degree to which an evaluation tool is logically sound, with no conflicting factors).

A number of projects (Bajraktarevic *et al.*, 2003; Carver *et al.*, 1999; Grigoriadou, *et al.*, 2001; Kwok & Jones, 1985; Triantafillou *et al.*, 2002; Wolf, 2002) are currently investigating the use of learning styles as a user modelling tool in AEH; the proposed taxonomy is thus of immediate use and valuable to many co-workers and colleagues. The proposed taxonomy attempts to consolidate these many varied approaches into a more coherent overview, so that developers of AEH systems might compare and contrast similar learning style models. This parallels the work done by Allert *et al.* (2003), who discusses the use of metadata in creating educational resources. It is hoped in time that standardized metadata for learning styles could be produced and utilised by AEH developers.

The application of such techniques in a real system could bring about severe problems. For example, let us think of the practical aspects of the application of the seven high level ADAPT design dimensions. If each of these seven dimensions is binary, there are 27 different combinations. Therefore, in theory, there are 27 different combinations of learning material that would need to be prepared, which is obviously impractical. A balance between a) aspects to be taken into account to provide personalization and adaptation and b) workload to develop the necessary learning material, needs to be achieved. This might also be solved with automation of some of the aspects of authoring, as is proposed in Cristea (2004).

Whilst the proposed taxonomy is in its infancy, the authors hope that the community will embrace and discuss the ideas presented. Of course this is just the first step, there are many aspects of the AEH design patterns that are left to explore. However in doing so we move towards a series of guidelines and rules that will aid everyone in the creation of an AEH system or teaching material best suited for their purpose with the minimum of effort.

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